

Connecting SimKit Discrete Event Simulation (DES) and the Naval Simulation System (NSS) via Web Services for Extensible Modeling & Simulation (XMSF)-Capable Analysis

Don Brutzman, Arnie Buss and Curt Blais

brutzman@nps.navy.mil +1.831.656.2149

Modeling Virtual Environments & Simulation (MOVES)

Naval Postgraduate School, Monterey California USA

1. Overview

This project overview describes ongoing research and development using a transformational analytical modeling framework. Web services are used in an innovative way to connect multiple model components in a flexible, scalable, extensible architecture. Following the strategic trajectory of the XMSF effort, this work starts first with functioning exemplars, then progresses to supporting tools, and then steps up to world-class modeling challenges, analysis and results.

Key sources of functionality for these efforts include:

- SimKit discrete event simulation application program interface (API) developed by the Naval Postgraduate School (NPS),
- Combat XXI under development by the Army and Marine Corps at the Army TRADOC Analysis Center (TRAC), White Sands, which already incorporates SimKit,
- Naval Simulation System (NSS) developed by SPAWAR Systems Center, San Diego.

The following projects are being performed in 2004 for U.S. Navy CNO staff, specifically OPNAV N81, as portions of the World-Class Modeling (WCM) family of projects. The first three projects are establishing web-services interoperability and logical connectivity between existing systems: SimKit/Combat^{XXI}, Naval Simulation System (NSS) and the X3D-based Scenario Authoring and Visualization for Advanced Graphical Environments (SAVAGE) model archive. The final two projects will conduct advanced analysis using this set of hybrid discrete-event simulation (DES) tools.

- WCM-14: Special Operations Forces (SOF) Modeling (Detailed) for PR-07
- WCM-16: SAVAGE to Model Force Protection/Anti-Terrorism Modeling for PR07
- WCM-28: Analytical Workbench for Simkit Modeling
- WCM-15: Joint Forcible Entry Options (JFEO) Modeling in Combat XXI for PR07
- WCM-19: Improve Strike Module (Detailed) in Combat XXI for PR07
- WCM-09: Battalion Combat Modeling Module

Effective hybrid analysis taking advantage of the integration of components from these sources will provide demonstration of a broad, joint set of warfare capabilities. All work will reflect precepts of the XMSF program, utilizing Internet technologies and Web services for common data representations, semantics, protocols, and interchange. This work is expected to lead to application of the new analytical modeling capabilities to operational problems of interest that demonstrate the repeatable, scalable benefits of this technical approach.

2. Background

The Office of the Secretary of Defense (OSD) has identified a new Analytical Agenda seeking to transform the way the Department of Defense applies Modeling and Simulation (M&S) to challenges of today's warfighters. Primary focus areas of the analytical Agenda are:

- Service/Agency POM Development
- Studies: Program Budget Review, Defense Planning Guidance (DPG), Analyses of Alternatives (AOA)
- Capabilities-Based Future Force Planning and Future Requirements

The 2001 Quadrennial Defense Review (QDR) defined Capabilities-Based Planning, stating it "shifts the focus of U.S. Force planning from optimizing for conflicts in two particular regions -- Northeast and Southwest Asia -- to building a portfolio of capabilities that is robust across the spectrum of possible force requirements, both functional and geographical." To support this concept, tools are needed that enable analysts to examine a wide range of variability in priority Red, Blue, and Green factors, in order to achieve a broad portfolio of military capabilities that will perform robustly in an uncertain future environment and that are linked to Joint Concepts of Operations. This requires a new class of M&S capabilities, moving away from monolithic, closed system designs to open, M&S frameworks that permit modular, loosely coupled components to be rapidly integrated to create agile analytical capabilities to address the variety of missions conducted by today's warfighters. These tools must be flexible, extensible, scalable to a variety of scales of combat, re-usable, executable in a desktop/laptop environment, convenient to use, able to exploit the best methods (functionality) available in various domains, and not bound to traditional approaches to combat modeling but able to model future concepts and to provide a framework for introducing wholly new concepts of warfare.

The pattern for success in this transformational endeavor is the Internet and World Wide Web. This computational environment has shown the capability to scale to global dimensions by providing a low cost-of-entry through establishment of standards for exchange of information across any platform and operating system. Recent emergence of the Extensible Modeling and Simulation Framework (XMSF) program from the Defense Modeling and Simulation Office (DMSO) reflects the desire to exploit the great success of Internet technologies, and the massive commercial investment in the advance of those technologies, to meet DoD M&S requirements across analysis, training, acquisition, and experimentation. XMSF is defined as a composable set of standards, profiles, and recommended practices for web-based M&S. The foundational precept is that Internet technologies, including Extensible Markup Language (XML) based languages and service-oriented architectures (e.g., Web services), will enable a new generation of distributed M&S applications to emerge, develop, and interoperate.

3. Scope

Paramount project objectives are to produce a new dynamic for analytic capabilities by connecting diverse analytic tools using Web services. This effort involves software analysis, design, and development to review and upgrade existing code bases (SimKit and NSS) leading to integration of functional capabilities with the SimKit-based Combat XXI simulation. The effort also requires design and conduct of analyses addressing specific operational problems. Tasking requires expertise in Operations Research, SimKit Discrete Event Simulation software package, the NSS code base, along with the establishment and management of Open Source software archives for long-term viability.

Simkit Discrete Event Simulation (DES) Overview

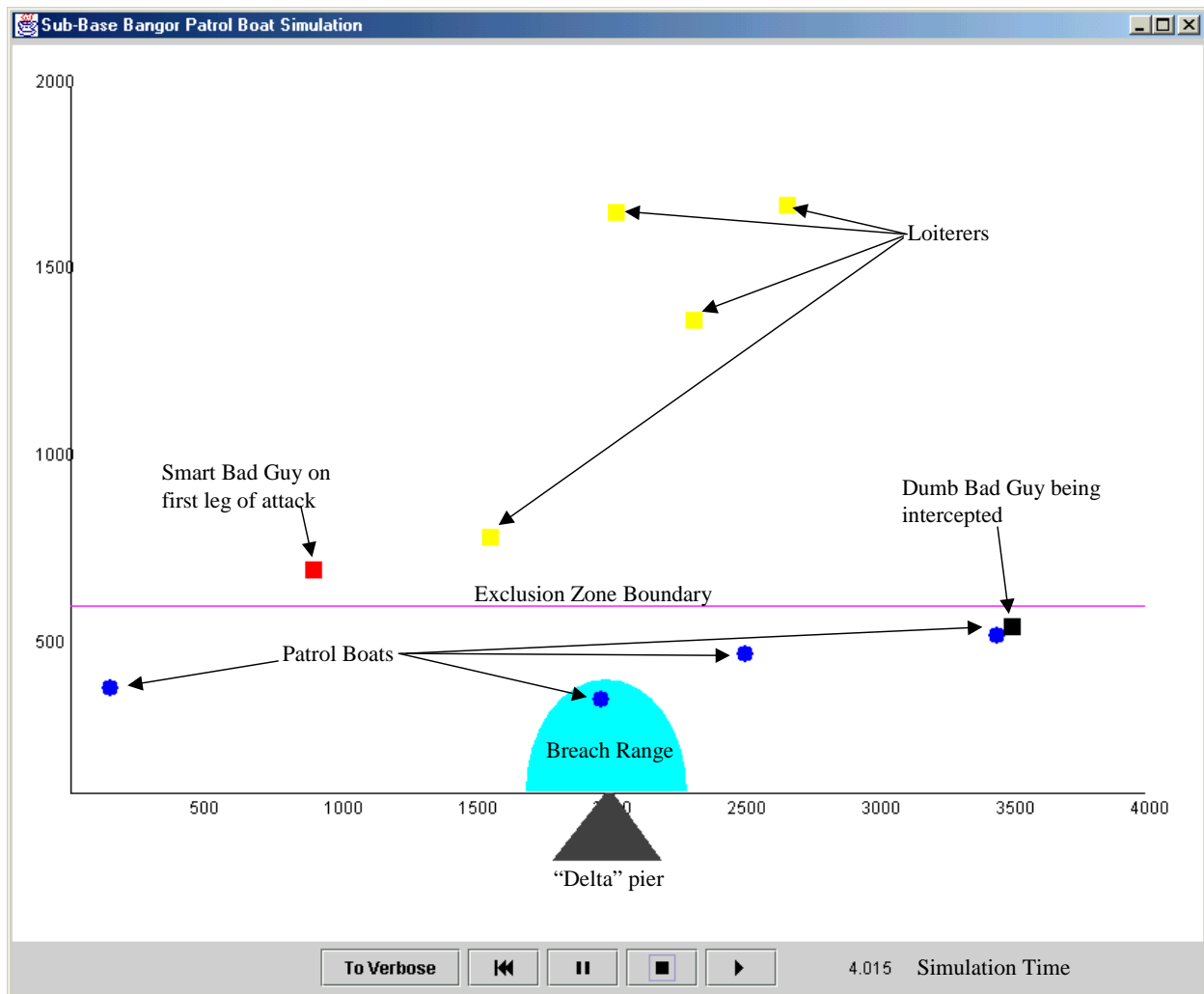
WHAT IS SIMKIT?

- A package (API) for easily creating Discrete Event Simulation (DES) models
- Written in Java, runs on any Java 2 platform and modern web browsers
- Open Source
- Installable from the web
- Small execution footprint
- Simkit is the simulation engine for Combat XXI, the Army's next-generation premier ground combat simulation (replacing CASTFOREM)

WHAT ARE THE ADVANTAGES OF SIMKIT?

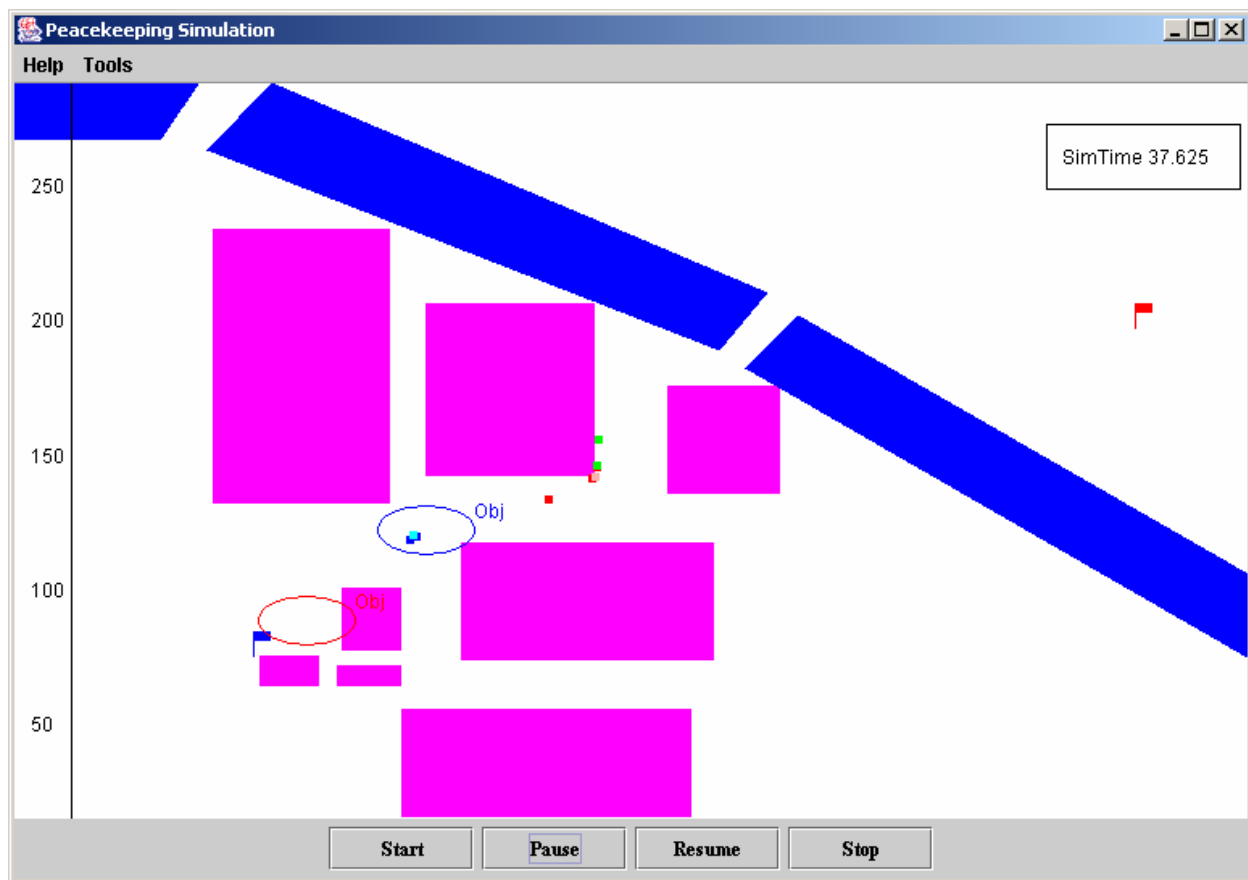
- Based on Event Graph Methodology, the simplest and most flexible formalism for DES modeling
- Supports component-based simulation modeling (LEGO Framework)
- Extremely flexible and extensible
- Allows separation of model constructs from data gathering without compromising ability to estimate Measures of Effectiveness (MOEs)
- Formalism ensures that any possible MOE can be estimated from properly constructed model
- Use of listener patterns supports very loose coupling of components
- Wide range of situations capable of being modeled in Simkit

The following image is a screenshot from an animation of the scenario. The various entities are each controlled by a distinct set of behaviors specified by their own “Mover Manager.” Since the animation is very loosely coupled with the simulation model, the same model is used both for display of individual runs as well as for batch runs in non-graphical mode for analysis.



Screenshot of Waterfront Force Protection Model (Childs, 2002)

Yet another example of Simkit’s use in unconventional settings is a model of peacekeeping operations in an urban environment. What makes such situations challenging for traditional DoD wargaming models is that the measures of performance are often inverted. For example, instead of attempting to maximize enemy casualties, peacekeeping operations seek to minimize casualties of the antagonists. The following is a screenshot from an agent-based model of peacekeeping operations written in Simkit (Erlenbruch, 2002):



Agent-Based Model of Urban Peacekeeping (Erlenbruch, 2002)

SOME RECENT NPS THESES USING SIMKIT

MARGOLIS, MICHAEL, Captain, U.S. Marine Corps, "Operational Availability and Cost Trade-Off Analysis for the Multi-Mission Maritime Aircraft," MS in Operations Research, September 2003.

NAWARA, TERRENCE, LT U.S. Navy, "Tactical Route Planning for Submarine Mine Detection and Avoidance," MS in Operations Research, September 2003, Advisor: Steven E. Pilnick.

FUTCHER, FRANK W., Lieutenant Commander, USN, "Selective Offload Capability Simulation (SOCS): An Analysis Of High Density Storage Configurations," MS in Operations Research, September 2003, Advisor: Kevin R. Gue.

HAVENS, MICHAEL E., Lieutenant, U.S. Navy, "Dynamic Allocation of Fires and Sensors," MS in Operations Research, September 2002.

CHILDS, MATTHEW D., Lieutenant Commander, USN, "An Exploratory Analysis of Water Front Force Protection Measures Using Simulation," MS in Operations Research, March 2002.

ERLENBRUCH, THOMAS, Captain, German Army, "Agent-based Simulation of German Peacekeeping Operations for Units up to Platoon Level," MS in Operations Research, March 2002.

Naval Simulation System (NSS) Overview

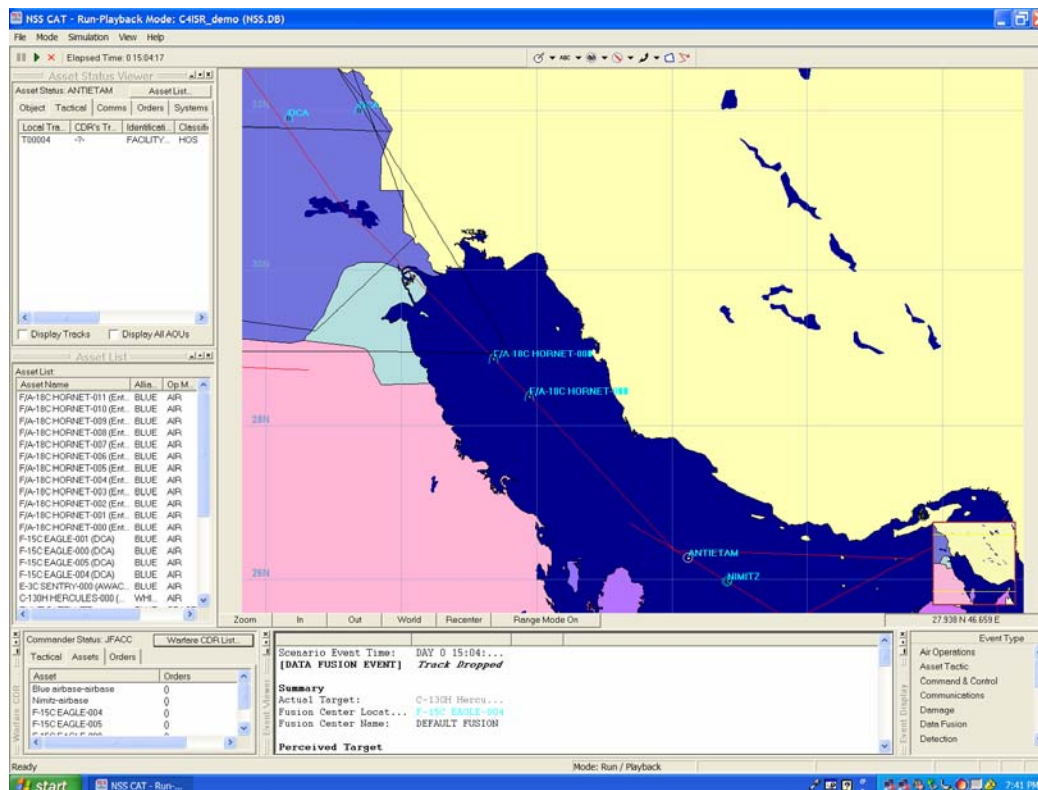
WHAT IS THE NAVAL SIMULATION SYSTEM (NSS)?

- Computer-based framework for C4ISR-centric multiwarfare simulation
- Constructive, analytical simulation model of naval theatre operations supporting:
 - Naval and Joint operations planning and decision support
 - C4ISR analyses/assessments
 - Fleet exercises and experiments
 - Fleet training
- Representation of surface, subsurface, air, ground, and space assets
- Intended to provide valid warfare models, certified data to populate the models, simulation capability to execute the models over time, and support tools to assist user in scenario setup and analysis of results
- Program Management: NAVAIR under sponsorship of CNO (N6M) and COMPACFLT (N64).
- Prime Development Contractor: Metron, Inc., Solana Beach CA
- Support and V&V Contractor: Rolands & Associates Corporation, Monterey CA
- Under development since 1994 and used for numerous analysis support efforts for the Fleet and DoD acquisition communities
- Written in C++, runs on any PC under Windows
- Allows configuration of multiple “study nodes” on a network for distributing replications to multiple machines

PRIMARY SOFTWARE COMPONENTS

- NSS Client Applications. Permit user visualization and control of system processes, including simulation instance development, scenario plan development, interactive execution, batch run management, and post-processing. Includes:
 - COA Analysis Tool (CAT). Facilitates detailed, comprehensive NSS scenario file generation. Provides maximum user flexibility in accessing simulation capabilities.
 - Warfare-Specific Support Tools. A set of focused tools for Fleet warfare plan evaluation: Strike Warfare Decision Aid to develop candidate Master Air Attack Plan; Targeting Management System to generate the strike target list; Theater Missile Defense COA Support Tool to evaluate TBMD RECCE plans.
 - CAT Demo Tool. For playback presentation of completed simulation event streams to analysis decision makers.
 - Network Monitor. To facilitate user monitoring and override control of NSS network activities.
 - Database Modernizer. Converts older versions of the NSS database to the most current format, thus making them compatible with the current software version.
 - Configuration Editor. Used to determine the current NSS installation configuration.
 - NSS Server. Manages NSS simulation execution resources on the local area network (LAN). Coordinates network access to the NSS Database by NSS Clients and Model Engine Nodes.

- NSS Model Engine Node. Parses and executes user defined simulation scenarios as directed by the Server. Generates scenario event stream, MOE output data, and execution status. Installed as a module on one or more network machines.
- NSS Database. Contains persistent and volatile data constructs that are processed by the NSS Server, Clients, and Model Engine Nodes. The NSS Database resides within the OODBMS Server (see Required COTS Software below).



NSS map view and status screen during model execution of a user-defined scenario

- Commercial Off-the-Shelf (COTS) Software
 - Database Management System Server. Contains the NSS Database. Interfaces exclusively with DBMS Clients. Note: NSS development to date has been tightly coupled with ObjectStore OODBMS.
 - Database Management System Client. Facilitates NSS component access to the NSS Database via the DBMS Server. Note: NSS development to date has been tightly coupled with ObjectStore OODBMS.
 - Spreadsheet Application. Facilitates automated manipulation and presentation of NSS interaction table input data and MOE output data. Note: NSS development to date has been moderately coupled with Microsoft Excel.
 - Word Processor. Used to generate preformatted Software Change Requests (SCRs). Note: NSS development to date has been loosely coupled with Microsoft Word.
 - Mathematical Optimization Application. Used in conjunction with NSS optimization code to provide plan recommendation services. Used by the warfare-specific support tools. Note: Currently, NSS optimization services are provided using the COTS GAMS linear and integer programming (LP/IP) solver package.

SOME RECENT NPS THESES USING NSS

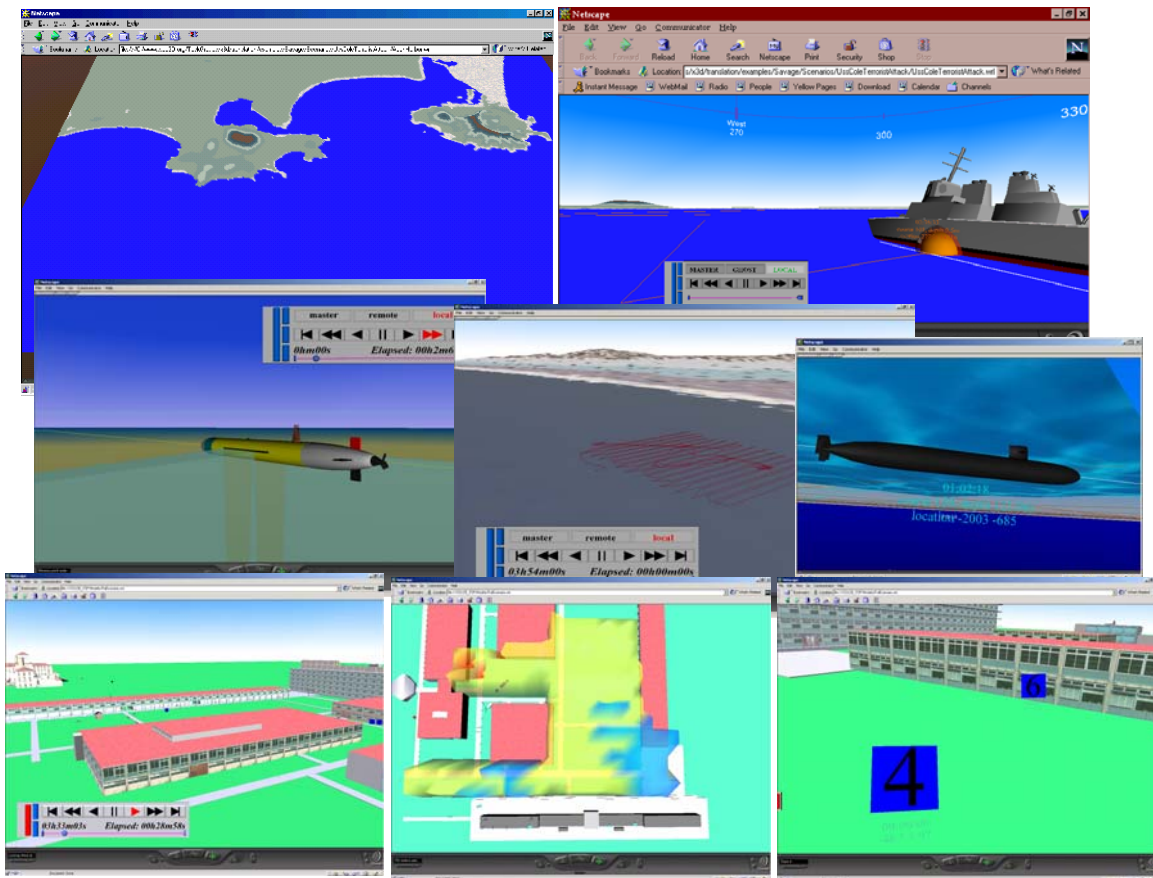
HOUT, GARY, NSWC-Crane, "Toward XML Representation of NSS Simulation Scenario For Mission Scenario Exchange Capability," MS in MOVES, September 2003.

CLAUDIO, JESUS, CPT U.S. Marine Corps, "An Aircraft Survivability Analysis Using Naval Simulation System," MS in Aeronautical Engineering, September 2003. SECRET

Scenario Authoring and Visualization for Advanced Graphical Environments (SAVAGE) Overview

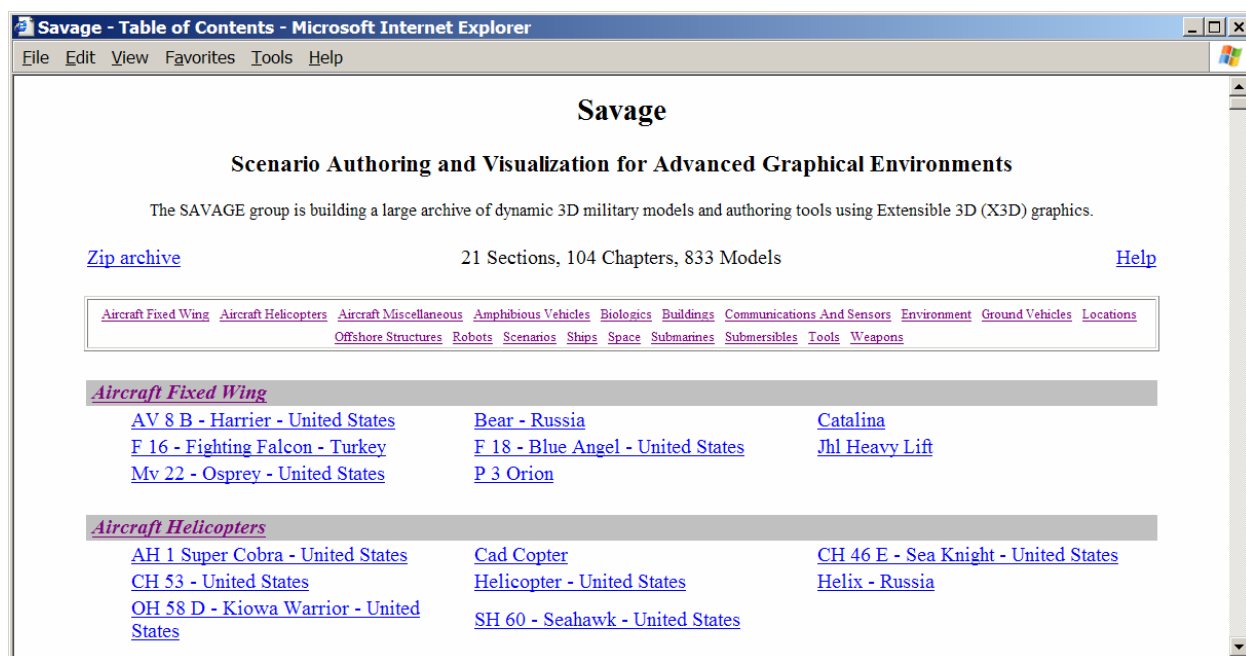
WHAT IS SAVAGE?

- A library of military 3D models, authoring tools, physics-based models and scenarios
- Available on the Internet at <http://web.nps.navy.mil/~brutzman/Savage/contents.html>)
- Written in Extensible 3D Graphics (X3D), the next-generation 3D standard for the World Wide Web (http://www.web3d.org/fs_specifications.htm). X3D offers an XML encoding that captures and extends the Virtual Reality Modeling Language (VRML) standard.



Hundreds of scenarios and projects can be rapidly modeled using the SAVAGE 3D library.

The SAVAGE library has been used for reconstruction of real-world events such as the terrorist bombing of the USS Cole in Aden Harbor (top row), the USS Greenville/Ehime Maru collision (far right, second row above), as well as for Autonomous Underwater Vehicle (AUV) mission planning and visualization (left and middle pictures, second row) and for visualization of Joint Experimentation Limited Objective Experiment scenarios (bottom row).



The SAVAGE library of models: <http://web.nps.navy.mil/~brutzman/Savage/contents.html>

WHAT ARE THE BENEFITS OF SAVAGE?

- Over eight hundred open source 3D models, physics-based models, model components, authoring tools, and scenarios to facilitate rapid development of immersive, interactive, and dynamic Web-based scenes
- Models are readily incorporated into applications built using the Xj3D open source implementation of the X3D standard, freely available for use in building Web-based 3D applications
- Extensive and consistent documentation in all model files
- Continuing expansion of the library through model submissions from beginning and advanced X3D courses (MV3204 and MV4205)
- Models and tools have been used for detailed reconstruction of real-world events such as the USS Greenville and Ehime Maru collision and the terrorist bombing of the USS Cole in Aden Harbor

SOME RECENT NPS THESES USING SAVAGE

HUTTON, CLAUDE, MAJ USMC, "3D Battlespace Visualization Using Operational Planning Data," MS in Computer Science, September 2003.

NEUSHUL, JAMES, CAPT USMC, "Interoperability, Data Control and Battlespace Visualization using XML, XSLT and X3D," MS in Computer Science, September 2003.

HARNEY, JAMES, LT U.S. Navy, "Analyzing Anti-Terrorist Tactical Effectiveness of Picket Boats for Force Protection of Navy Ships Using X3D Graphics and Agent-Based Simulation," MS in Computer Science, March 2003.

NICKLAUS, SHANE, MAJ USMC, "Scenario Authoring and Visualization for Advanced Graphical Environments," MS in Information Technology Management, September 2001.

Extensible Modeling & Simulation Framework (XMSF) Overview

<http://www.movesinstitute.org/xmsf/xmsf.html>

WHAT IS XMSF?

- The Extensible Modeling and Simulation Framework (XMSF) provides the technical basis for transformational interoperability via XML interchange, profiles, and recommended practices for web-based modeling & simulation.
- Broad technical interoperability is provided by open standards, XML-based markup languages, Internet technologies, and cross-platform Web services.
- Supports diverse distributed modeling and simulation applications. Also enables simulations to interact directly and scale appropriately over a distributed network through composable and reusable model components.
- Employs mainstream practices of enterprise-wide software development.
- Provides support for all types and domains of modeling and simulation (constructive, live, virtual, and analytical).
- Excellent support for ISO Extensible 3D (X3D) Graphics Specification with industry-academic-government activity in multiple standards consortia

WHAT ARE THE ADVANTAGES OF XMSF?

- Supports Open Standards in Web, Internet, and XML technologies. Web services allow self-validating syntax and semantics to achieve cross-cutting interoperability in modeling and simulation.
- Development and acceptance of common data and metadata standards provides semantic consistency among systems and services.
- Profiles are specification suites based on international standards, which define common capabilities for content production user/application support.
- Data-driven conversion capabilities and application ubiquity provides both best business case and best technical case on a DoD-wide scale.

WCM-14 Special Operations Forces (SOF) Modeling Project

Intended Outcomes

- **Framework Definition:** Assess existing programs and capabilities. Identify capabilities of SimKit, NSS, and Combat XXI.
- **Standards Identification:** Identify specific standards to be applied to the program, focusing on research directions of the XMSF project and warfare information modeling efforts such as the Battlespace Management Language (BML) and Battlespace Generic Hub. Define the basis for information interchange.
- **Design and Develop Baseline Model Framework:** Create the initial architectural framework for the analytical model, designing functions for input display, scenario construction, data extraction, and display of results. Integrate selected NSS C4ISR and Naval warfare functional capabilities with Combat XXI ground engagement functionality.
- **Demonstration Scenario:** A FORCEnet scenario will be designed and implemented using functional components within the new framework. The demonstration will be a notional SOF scenario that measures the contribution of C3 links to the mission and a Fires network to support Joint ops ashore.

WCM-16 SAVAGE for Force Protection/Anti-Terrorism (AT/FP) Modeling

Intended Outcomes

- **Requirements Analysis and Software Design:** Working with N81 analysts, determine functional capabilities needed to explore FP/AT problems of interest to N81. Perform software design to modify and expand capabilities of the NPS planning tool to meet required capabilities for the studies.
- **Software Implementation and Test:** Implement and test software modifications to the NPS FP/AT planning tool. Demonstrate new and enhanced capabilities of the model to perform desired studies. Work will include upgrading the implementation to use the SimKit discrete event simulation library.
- **Problem Definition, Scenario Development, Model Execution and Analysis:** Perform systems analysis to specify the analysis question, identifying the setting, threat and force protection characteristics to be studied. Identify various options to be investigated and design experiments to be run. Determine an appropriate operational setting for the study. Input necessary force structures, weapons characteristics, initial conditions, and other database and scenario initialization data needed to represent the scenario in the model. Conduct necessary model replication runs to obtain statistical data supporting analysis of results. Prepare a document describing the analysis problem, experimental design, scenario and model outcomes, with lessons learned and recommendations for further study.

WCM-28 Analytical Workbench for Simkit Modeling Project

Intended Outcomes

- **Model Capture and Upgrade:** Gather previously developed models from student theses and faculty research that used the SimKit software. Update those implementations for the current version of SimKit. Create a unified repository of the source code and model components with annotations facilitating access and use by an automated simulation development tool. Prepare a summary document describing the model capabilities collected into the repository. For example, simulations developed in the following student theses are candidates for the repository of models:
 - MARGOLIS, MICHAEL, Captain, U.S. Marine Corps, “Operational Availability and Cost Trade-Off Analysis for the Multi-Mission Maritime Aircraft,” MS in Operations Research, September 2003.
 - NAWARA, TERRENCE, LT U.S. Navy, “Tactical Route Planning for Submarine Mine Detection and Avoidance,” MS in Operations Research, September 2003, Advisor: Steven E. Pilnick.
 - FUTCHER, FRANK W., Lieutenant Commander, USN, “Selective Offload Capability Simulation (SOCS): An Analysis Of High Density Storage Configurations,” MS in Operations Research, September 2003, Advisor: Kevin R. Gue.
 - HAVENS, MICHAEL E., Lieutenant, U.S. Navy, “Dynamic Allocation of Fires and Sensors,” MS in Operations Research, September 2002.
 - CHILDS, MATTHEW D., Lieutenant Commander, USN, “An Exploratory Analysis of Water Front Force Protection Measures Using Simulation,” MS in Operations Research, March 2002.
 - ERLLENBRUCH, THOMAS, Captain, German Army, “Agent-based Simulation of German Peacekeeping Operations for Units up to Platoon Level,” MS in Operations Research, March 2002
 - FRICKE, CAROLYN S., Lieutenant Commander, U.S. Navy, “Operational Logistics Wargame,” MS in Operations Research, December 2001.
 - SAN JOSE, ANGEL E., Lieutenant Commander, Spanish Navy, “Analysis, Design, Implementation and Evaluation of Graphical Design Tool to Develop Discrete Event Simulation Models Using Event Graphs and Simkit,” MS in Operations Research, September 2001.
 - LENHARDT, THOMAS A., Captain, U.S. Marine Corps, “Evaluation of Combat Service Support Logistics Concepts for Supplying a USMC Regimental Task Force,” MS in Operations Research, September 2001.
 - MACK, PATRICK V., Lieutenant, U.S. Navy, “THORN: A Study in Designing a Usable Interface for a Geo-Referenced Discrete Event Simulation,” MS in Operations Research, September 2000.
 - TURNER, THOMAS E., Major, U.S. Marine Corps, “A Simulation of the Joint Tactical Radio System Bandwidth Requirements to Support Marine Corps Ship to Objective Maneuver in 2015,” MS in Operations Research, September 2000.
 - WOODAMAN, RONALD F.A., Major, U.S. Marine Corps, “Agent-Based Simulation of Military Operations Other Than War Small Unit Combat,” MS in Operations Research, September 2000.

- ARMO, KNUT R., Commander, Royal Norwegian Navy, “The Relationship Between a Submarine's Maximum Speed and Its Evasive Capability,” MS in Operations Research, June 2000.
 - AYDIN, ERHAN, LTJG, Turkish Navy, “Screen Dispositions of Naval Task Forces Against Anti-ship Missiles,” MS in Operations Research, March 2000.
 - LE, HUNG B., Lieutenant, U.S. Navy, “Advanced Naval Surface Fire Support Weapon Employment Against Mobile Targets,” MS in Operations Research, December 1999.
 - KRIZOV, DAVID P., Major, U.S. Marine Corps, “Tactical Exercise Review and Evaluation System,” MS in Operations Research, September 1999.
 - STERBA, JOHN R., Lieutenant, U.S. Navy, “Operational Maneuver from the Sea Logistics Training Aid,” MS in Operations Research, September 1999.
 - TROXELL, ANTHONY W., Lieutenant, U.S. Navy, “Naval Logistics Simulator,” MS in Operations Research, September 1999.
 - UTAAKER, INGE A., Commander, Norwegian Navy, “Distribution of Firing Directions in a Coordinated Surface-to-Surface Missile Engagement,” MS in Operations Research, September 1999.
 - GRABSKI, MARK V., Captain, U.S. Army, “Assessing the Effectiveness of the Battlefield Combat Identification System,” MS in Operations Research, June 1999.
 - HEATH, GARRETT D., Captain, U.S. Army, “Simulation Analysis of Unmanned Aerial Vehicles (UAV),” MS in Operations Research, June 1999.
 - POURNELLE, PHILLIP E., Lieutenant, U.S. Navy, “Component Based Simulation of the Space Operations Vehicle and the Common Aero Vehicle,” MS in Operations Research, March 1999.
 - SCHREPF, NORBERT, Captain, German Army, “Visual Planning Aid for Movement of Ground Forces in Operations Other Than War,” MS in Operations Research, March 1999.
 - ARNTZEN, ARENT, Lieutenant Commander, Royal Norwegian Air Force, “Software Components for Air Defense Planning,” MS in Operations Research, September 1998.
- **Analytical Simulation Workbench:** Design and develop a prototype Analytical Simulation Workbench to access the repository of model components and to assist the user in composing a simulation model from the existing components. Prepare a guidebook describing use of the Workbench to develop a simulation. Provide demonstration of the prototype workbench.
 - **Final Report:** Prepare a final report describing the design and development of the Analytical Simulation Workbench and providing a guidebook for use of the Workbench.

WCM-15 Joint Forcible Entry Options (JFEO) Modeling In Combat^{XXI}

Intended Outcomes

- **Problem Definition and Experimental Design:** Perform systems analysis to specify the analysis question, identifying the system and force characteristics to be studied. Identify various options to be investigated and design experiments to be run. Prepare a document defining the analysis to be performed.
- **Scenario Development:** Determine an appropriate operational setting for the study. Input necessary force structures, initial conditions, command relationships, communications characteristics and other database and scenario initialization data needed to represent the scenario in the integrated NSS/Combat^{XXI} model. Coordinate with NSS-specific scenario developers to ensure consistency in representations of the battlespace for the study. Prepare a scenario description document.
- **Model Execution and Analysis:** The ability to conduct a full study with the integrated NSS/Combat^{XXI} model is dependent on successful completion of the WCM-14 tasking (SOF Modeling for PR-07). Preparations for conducting the study can proceed as described above in Tasks 1 and 2 in parallel to software development efforts. A key checkpoint in the progress of the development effort and readiness of the software to support this study will occur in June 2004 during the Military Operations Research Society (MORS) Symposium to be held at NPS, Monterey CA. Based on the progress of the development effort, N81 will decide on the direction for continuation of this task (WCM-15); either:
 - Demonstration of the designed scenario with identification of shortcomings in the integrated framework that need to be addressed before it can be employed for the full study, or
 - Execution of the study by conducting necessary model replication runs to obtain statistical data supporting analysis of results. Prepare a document describing model outcomes, with lessons learned and recommendations for further study.

WCM-19 Improve Strike Module in Combat^{XXI} for PR07

Intended Outcomes

- **Problem Definition and Experimental Design:** Perform systems analysis to specify the analysis question, identifying the system and force characteristics to be studied. Identify various options to be investigated and design experiments to be run. Prepare a document defining the analysis to be performed.
- **Scenario Development:** Determine an appropriate operational setting for the study. Input necessary force structures, initial conditions, command relationships, communications characteristics and other database and scenario initialization data needed to represent the scenario in the integrated NSS/Combat^{XXI} model. Coordinate with NSS-specific scenario developers to ensure consistency in representations of the battlespace for the study. Prepare a scenario description document.
- **Model Execution and Analysis:** The ability to conduct a full study with the integrated NSS/Combat^{XXI} model is dependent on successful completion of the WCM-14 tasking (SOF Modeling for PR-07). Preparations for conducting the study can proceed as described above in Tasks 1 and 2 in parallel to software development efforts. A key checkpoint in the progress of the development effort and readiness of the software to support this study will occur in June 2004 during the Military Operations Research Society (MORS) Symposium to be held at NPS, Monterey CA. Based on the progress of the development effort, N81 will decide on the direction for continuation of this task (WCM-15); either:
 - Demonstration of the designed scenario with identification of shortcomings in the integrated framework that need to be addressed before it can be employed for the full study, or
 - Execution of the study by conducting necessary model replication runs to obtain statistical data supporting analysis of results. Prepare a document describing model outcomes, with lessons learned and recommendations for further study.

WCM-9 Battalion Combat Modeling Module

Intended Outcomes

- **Model Review:** Review (and document the review) of previous work on the hierarchy-of-models approach for the representation of large-scale combat (particularly the use of ATCAL Methodology by the Army's Concepts Evaluation Model (CEM) and the Air Force's Thunder model). The theoretical basis of all such applied implementations of G.M. Clark's ideas for developing such a hierarchy of models should be considered and taken as the point of departure for new theoretical developments in the hierarchy of models, as well as Taylor's new methodology for Lanchester attrition-rate coefficients. This review should identify functional requirements for multi-resolution modeling that can help generate an aggregated-force combat module for large-scale ground combat for a joint campaign model (implemented in a collaborative M&S framework involving NSS, Simkit, and Combat^{XXI}).
 - Taylor, J.G., "Research on Attrition Calibration (ATCAL) Methodology," Project Briefing presented to Director of U.S. Army Concepts Analysis Agency (CAA), December 8, 1997.
 - Taylor, J.G., Various Unpublished Working Papers concerning ATCAL prepared for the Simulation and Analysis Center (SAC) of OSD PA&E, Operations Research Department, Naval Postgraduate School, 1997-1998.
 - Taylor, J.G., Mansager, B.K., Buss, A.H., and Brown, R., "On the Theoretical Bases of the Attrition-Calibration (ATCAL) Method, with Applications to Algorithm Development," Proceedings of the First National Meeting of the Military Applications Society, Huntsville, AL, May 1998.
 - Taylor, J.G., Yildirim, U.Z., and Murphy, W.S., "Hierarchy-of-Models Approach for Aggregated-Force Attrition," Proceedings of the 2000 Winter Simulation Conference, Orlando, FL, December 2000.
 - Taylor, J.G., PowerPoint Slides for MV4656 "Low-Resolution Combat Modeling and Simulation," MOVES Academic Group, Naval Postgraduate School, May 1999 www.npsnet.org/~jtaylor/MV4656.html (especially Part G4 "Determining Numerical Values for Attrition-Rate Coefficients").
 - Taylor, J.G., "New Methodology for Lanchester Attrition-Rate Coefficients," Proceedings of the Millennium Attrition Symposium, Military Applications Society (MAS) of INFORMS, Houghton, MI, August 2001.

- **Theory Development:** Develop a theoretical basis for the hybrid methodology and establish the necessary models, with source code, at NPS to support follow-on software development work.
 - Determine theoretical and implementation shortcomings of previous and existing work on the hierarchy-of-models approach for modeling large-scale ground combat (especially ATCAL).
 - Develop theoretical basis for a new hybrid methodology for a ground-combat module within the context of a joint campaign model (implemented in a collaborative M&S framework involving NSS, Simkit, and CombatXXI); such a theoretical basis could lead to a spectrum of possible approaches for model implementation, characterized by different time lines of completion and risk.
 - Determine approaches and their limitations for sensitivity analysis.
- **Technical Report:** Produce a thorough technical report suitable for publication and broad use. The report will cover the strengths and limitations of current methodologies, in combination with possible new capabilities based on hybrid combinations of hierarchical combat models.
- **Follow-on Planning:** Propose the follow-on year 2 plan for implementation and evaluation.

Student Research Topics

Intended Outcomes

OPNAV N-81 has forwarded 10 research areas for investigation by NPS OR faculty and students in FY04. For each task undertaken, deliverables would be a project report and student thesis. Project funding provides support to the thesis advisor(s) and will support student travel, conference attendance, and other expenses for accomplishment of the work. Follow-on work in FY05 is possible. Topics are:

- Fog of War
- Decision Making in the face of uncertainty
- Impact of information overload on Commanders' Decision
- Afloat C2 Requirements and Limitations to Support Integrated Logistics
- Tracking of Medical Services to Support Casualties
- Effects of Morale on Combat Performance
- Training Effects on Combat Performance
- Measuring Impacts of Effects Based Operations
- Impact of Configuration of Command and Control Organizations on Network Centric Warfare
- Effectiveness of Using of Open Source Coding Practices for VV&A.

The objective is to initiate research and development of methodologies to measure the impact of areas previously not easily quantified. The areas of research listed are compiled from a list of difficult to understand areas identified by the Office of the Secretary of Defense and the Chief of Naval Operations. Students are expected to conduct the following steps in the chosen area of interest:

- Conduct a survey of the particular area of interest.
- Identify theories in the area of interest.
- Research data and methods supportable by commercial, military and government agencies.
- Select the best methodology to analyze the issues.
- Implement the methodology in a common collaborative analytical environment.
- Conduct analysis using the selected methodology (including Modeling and Simulation) in the area of interest.
- Report the results in a thesis.

Work will be conducted using the collaborative analytical framework being developed by the MOVES institute under the World Class Modeling effort. Modeling programs compatible with this effort include: SimKit, NSS and Combat XXI. Integration of components from these efforts will provide demonstration of a broad, Joint set of warfare capabilities. All work will be designed to be reused in future Modeling, Simulation and analysis efforts conducted by the OPNAV staff.

A Transformational Framework for Design, Development, and Integration of Simulation Models

Don Brutzman, Arnold Buss, LCDR Phillip E. Pournelle¹, Curt Blais, John Ruck²

MOVES Institute
Naval Postgraduate School
700 Dyer Road
Monterey, CA 93943

¹Deputy Chief of Naval Operations (OPNAV N81)
2000 Navy Pentagon (Rm 4D453)
Washington, DC 20350-2000

²Rolands & Associates Corporation
500 Sloat Avenue
Monterey, CA 93940

A new class of Modeling and Simulation (M&S) capabilities is needed to support transformational studies and analyses. Software architectures for analytical M&S tools need to move away from monolithic, closed system designs to open, M&S frameworks. New frameworks are needed to permit modular, loosely coupled components to be rapidly integrated to create agile analytical capabilities that can address the variety of missions conducted by today's warfighters. Tools built on these frameworks must be flexible, extensible, scalable to a variety of levels of combat, re-usable, executable in a desktop/laptop environment, convenient to use, able to exploit the best methods (functionality) available in various domains, and not bound to traditional approaches to combat modeling but able to model future concepts and to provide a framework for introducing wholly new concepts of warfare.

The Extensible Modeling and Simulation Framework (XMSF) is a composable set of standards, profiles, and recommended practices for web-based M&S that has been emerging as a framework capable of supporting these capabilities. This paper presents an architectural framework for design, development, and integration of simulation models built on XMSF using two existing simulations: Naval System Simulation (NSS) and Simkit. The capabilities will be demonstrated by a web-based simulation model composed using C4ISR elements from NSS together with land-based units from Simkit. The framework provides the needed flexibility with its use of standards suggested by XMSF, especially the exclusive use of Extensible Markup Language (XML) for data transfer. This ensures that additional components can be easily added to the framework without requiring substantial internal modification. This framework therefore illustrates the ability to achieve the requirements for M&S listed above.

Submitted to 72nd MORS Symposium, WG 31 Computing Advances in Military Operations Research

NSS, Simkit, and Combat^{XXI} using XMSF Web Services for Joint Modeling and Analysis

Curt Blais, Arnold Buss, Don Brutzman, John Ruck¹, Don McGregor

MOVES Institute
Naval Postgraduate School
700 Dyer Road
Monterey, CA 93943

¹Rolands & Associates Corporation
500 Sloat Avenue
Monterey, CA 93940

The elements of SEAPOWER 21...Sea Strike, Sea Shield and Sea Basing...commit the Navy to building, training and operating a force that maximizes the contribution of war winning capabilities in the joint battlespace anytime, anywhere. Tying the three pillars of SEAPOWER 21 together is FORCEnet. FORCEnet is the operational construct and architectural framework for naval warfare in the information age, integrating warriors, sensors, command and control, platforms, and weapons into a networked, distributed and joint combat force. SEAPOWER 21 will be implemented by a Global Concept of Operations (GLOBAL CONOPS) that will provide our nation with widely dispersed combat power from platforms possessing unprecedented joint warfighting capabilities.

The study measures the impact of FORCEnet, improved C4ISR, Seabased forces, SeaStrike and the other pillars of SEAPOWER 21 on the joint ground warfight. It utilizes the improved joint modeling capability based on a composite model using Naval Simulation System (NSS) for sea strike and the CombatXXI to model the ground combat. The models are linked using the Extensible Modeling and Simulation Framework (XMSF), which utilizes web services. This implementation is an exemplar for a transformational framework for design, development, and integration of simulation models, a larger effort to provide modeling and simulation interoperability using principles of XMSF.

Submitted to 72nd MORS Symposium, WG 29 Modeling Simulation and Wargaming

Simkit Analysis Workbench for Rapid Construction of Modeling and Simulation Components

Arnold Buss, Don Brutzman, Curt Blais, Rick Goldberg, Don McGregor, John Ruck¹

MOVES Institute
Naval Postgraduate School
700 Dyer Road
Monterey, CA 93943

¹Rolands & Associates Corporation
500 Sloat Avenue
Monterey, CA 93940

A recurring dilemma in the use of simulation models for analytic support of decision-making has been the length of time required to build the simulation model. Although emerging simulations have improved over legacy models, the problem persists. It is particularly difficult to create a simulation model using existing tools that captures only the desired elements affecting the performance measures to be studied. Additionally, there is often a lack of rigorous methodology underlying the model's design.

Simkit is an Object-Oriented API for creating discrete Event simulation (DES) models in Java. Based on a solid Event Graph methodology, Simkit has been used to quickly create models in a wide range of areas, including logistics and operational support, undersea models, and models that evaluate algorithms for allocation of weapons and sensors to targets in ground combat. Simkit's component-oriented approach facilitates the composition of models using some pre-built and some custom simulation components.

This work demonstrates a Graphical User Interface (GUI) for the creation and analysis of Simkit models. It utilizes XML to represent the components, so there is built-in interoperability with many other tools. Specifically, simulation components and models designed in this manner will be capable of interacting with models with Extensible Modeling and Simulation Framework (XMSF) capabilities. In component design mode, a new component is created by drawing the Event Graph and filling in parameters, so that the simulation modeler need not be a sophisticated programmer. In component construction mode, components are hooked together to create a model. In analysis mode, the models are exercised and run according to the desired experimental design. The workbench also has a number of exemplar models that have been extracted from recent NPS Master's Theses.

Submitted to 72nd MORS Symposium, WG 26 Analysis of Alternatives